

REVIEWS.

ART. XVI.—*Disinfection.*

1. *Traité des Désinfectants sous le Rapport de L'Hygiène Publique, etc. etc.* Par M. A. CHEVALLIER, Pharmacien-Chimiste, Officier de la Légion d'Honneur, etc. etc. Paris, 1862. pp. 180.
2. *Third Report of the Commissioners appointed to inquire into the Origin and Nature of the Cattle Plague.* London, 1866.
 - a. *Microscopical Reséarches on the Cattle Plague.* By LIONEL S. BEALE, M. B., F. R. S.
 - b. *On Disinfection and Disinfectants.* By R. ANGUS SMITH, Ph.D., F. R. S.
 - c. *On the Application of Disinfectants in Arresting the Spread of Cattle Plague.* By WM. CROOKES, F. R. S.
3. *On Deodorization and Disinfection.* By THOS. HERBERT BARKER, M. D., F. R. S. E. (Hastings Prize Essay.)
4. *A Manual of Practical Hygiene, prepared especially for use in the Medical Service of the Army.* By E. A. PARKES, M. D., F. R. S. Second edition. London, 1866.
5. *Proceedings and Debates of the Third National Quarantine Convention, held in the City of New York.* 1859.
6. *Disinfection.* By E. R. SQUIBB, M. D. Brooklyn, N. Y. (Report of the Committee on Disinfection to the Academy of Medicine.)
7. *Chemistry, Theoretical, Practical, and Analytical, as Applied and Relating to the Arts and Manufactures.* By Dr. SHERIDAN MUSPRATT, F. R. S. E., M. R. I. A., F. G. S. Vol. I. p. 556. Art. "Disinfection."
8. *Hints on the Control and Prevention of Infectious Diseases in Camps, Transports, and Hospitals.* By ELISHA HARRIS, M. D. Sanitary Commission Document, S.
9. *On the Utility and Application of Heat as a Disinfectant.* By ELISHA HARRIS, M. D. (Proceedings of the Fourth National Sanitary and Quarantine Convention, 1860.)
10. *North British Review*, June, 1866. Art. VIII.—Disinfection.
11. *Annual Report of the Metropolitan Board of Health, 1867.* New York, 1867.

HISTORY.—The history of the practice of disinfection is full of interest. Many agents employed for this purpose, and most approved by the moderns, were known to the ancients. Thus, we find that sulphurous acid, recently strongly advocated by Dr. Polli, of Milan, and Dr. Dewar, of Scotland, was used by Ulysses to destroy the odour and toxic properties, of the gaseous products of putrefactive decomposition (*Homer's Odyssey*, Book xxii.), and the tar compounds were the chief agents in the ancient process of embalming. These became "lost arts," to be re-discovered in modern times. The ancients were also well acquainted with many of

those hygienic evils against which disinfection is directed. The Romans early learned the dangers of crowding, and the necessity for a proper system of sewerage. Hence the height of the houses was restricted to seventy feet, and the streets widened, by Augustus. The sewers (*cloacæ*) of Rome were of vast size and great extent. According to Livy (lib. i. cap. xxxviii.), these were first made by Tarquinius Priscus, but the principal sewer (*cloaca maxima*) was built by Tarquinius Superbus.¹ There were openings at regular distances to permit the surface-drainage and sewerage to flow into the sewers (*Horat. Sat.*, ii. 3, 242),² and a police force³ was kept for the purpose of cleaning out these receptacles. The water with which the city was so liberally supplied was used (*Plin.*, xxxvi. 15) to flush the sewers, and carry their contents into the Tiber. Our modern schemes of drainage and purification of sewers is not much in advance of the ancient practice.

Boyle, in the early part of the seventeenth century, revived the study of disinfectants and the practice of disinfection. Pringle, in 1750; Guyton de Morveau, in 1773; and Fourcroy, in 1791, proposed agents for disinfection. Sir John Pringle, as the result of his "Experiments on Septic and Antiseptic Substances," recommended "various salts, and the astringents and gum resins* of vegetables and fermenting liquors." Guyton de Morveau strongly recommended chlorhydric acid gas, and Fourcroy was the first to propose the use of chlorine (Chevallier).

The actions and uses of disinfectants have been placed upon a more secure and scientific basis by the labours of recent chemists. Conspicuous amongst these are Angus Smith, Crookes, Herbert Barker, Parkes, and Chevallier, whose works are named at the head of this article. We should not omit mention of the very important contributions made by our own countrymen, Drs. Elisha Harris, of New York, and Squibb of Brooklyn—especially the former, who is entitled to the merit of being one of the most active and practical sanitarians in these States.

SUBSTANCES TO BE ACTED UPON BY DISINFECTANTS.—To give scientific value to the knowledge gained in the study of disinfectants, and accuracy to the methods of applying them in practice, it is necessary to know something of the physical and chemical characters of morbid matter, or at least of its habitat. This knowledge is, as yet, unattainable; nevertheless, some of the authors before us have attempted to achieve it.

Mr. Crookes classes the morbid matters, "the putrefactive products of animal and vegetable matter," as follows:—

Sulphuretted Hydrogen.	Hydrogen.
Phosphuretted Hydrogen.	Carbonic Oxide.
Ammonia.	Nitrogen.
Phosphorus and Nitrogen, bases of complex constitution.	Various animal and vegetable products of little or no activity; and
Acetic, Butyric, Valerianic, &c. Acids.	The special virus of infection.
Carburetted Hydrogen.	

Of all these substances none are positively known to produce any specific form of disease—except, of course, the special virus, whose chemical and physical properties are unknown. The actions of the others have

¹ Foros in circo faciendos cloacamque maximam receptaculum omnium purgamentorum urbis, sub terram agendam.—*Titi Livii*, lib. i. cap. lvi.

² ——— Qui sanior ac si

Illud idem, in rapidum flumen jaceretve cloacam?

³ Curatores cloacarum.

been studied, and the means of destroying them, chemically, are sufficiently understood. Unfortunately our disinfectants are directed chiefly against the least dangerous, and are not known to be efficacious, except to a very limited extent, against the real morbid matter—the special virus. Although the products of the putrefactive decomposition of animal and vegetable matters do not produce specific forms of disease, they unquestionably exercise no little influence as predisposing causes, especially of the zymotic diseases. Hence it is a hygienic problem in every civilized community, how to get rid of these products. In all large cities the gaseous compounds of hydrogen with carbon, sulphur, phosphorus, nitrogen, and the volatile fatty acids, are given off from the cesspools and sewers. During the late epidemic of cholera in Cincinnati, we saw numerous instances of the influence of sewage gases in increasing the virulence and mortality from that disease. Thus, tenement-houses situated about the open mouths of sewers, in several localities under our observation, were almost depopulated by cholera, when the other hygienic conditions were not unfavourable.

Herbert Barker, in the course of some experimental investigations on malaria and miasmata, has shown by direct experiment the deleterious influence of sewer-gases. Three dogs, confined in a box into which sewer-gases, consisting of carbonic acid, sulphuretted hydrogen, and sulphide of ammonium were conveyed, suffered from vomiting, purging, and a febrile state. In some similar experiments we failed to induce these effects, probably because the trial was not continued a sufficient length of time; for introducing, at the end of a week, an unexpectedly large amount of gas, the life of the animal experimented on was destroyed in an instant. Parkes has collected numerous observations, for and against the influence of sewer-gases in the production of disease, and has embodied his conclusions in the following statement:—

“Every one must have seen instances in which headache, sickness, diarrhoea, general malaise, and, after a certain time, great depression of health, with more or less anæmia, were produced. In some cases I have known decided febrile attacks, lasting three or four days, and attended with great headache and anorexia. In some cases, houses into which there has been a continued escape of sewer air, have been so notoriously unhealthy that no person could live in them, and this has not been only from the prevalence of fever, but from other diseases.”

Again, when discussing the influence of fecal emanations, the same author remarks:—

“To sum up, the diseases produced by fecal emanations on the general population seem to be diarrhoea, bilious disorders, often with febrile symptoms; dyspepsia, general malaise, and anæmia—all these being affections of digestion or sanguification; typhoid fever is also intimately connected with sewage emanations, either being their direct result, or, more probably, being caused by specific products mixed with the sewage.”

These statements do not militate against the position which we have assumed, viz: that no specific disease has been shown to be caused by the gaseous products of putrefaction of animal and vegetable matter. A toxic effect is undoubtedly produced by these gases, but it is necessary to recognize the difference between the action of a *virus* and a *poison*. Mr. Crookes makes some very satisfactory observations on this point.

“No poison yet known to chemists can approach, even in a faint degree, the tremendous energy of the active agent of infectious diseases. A poison may be organic, but it is not organized. It may kill with far greater rapidity than the

virus of infection, but unlike the virus, it cannot multiply itself in the animal economy to such an extent as to endow, within a few hours, every portion of its juices with the power of producing similar results. A virus, on the contrary, renders the liquids of an infected animal as virulent as the original germ. Strychnia may be regarded as the type of a poison, and vaccine matter as the type of a virus."

This difference in the character of virus and poison is fundamental, and if generally regarded, would, as Mr. Crookes suggests, be more convenient, and tend to promote accuracy of thought. The gaseous products of the putrefaction of animal and vegetable matter, must, therefore, be considered as poisons, which, if taken into the organism in sufficient quantity, will produce certain toxic effects, but do not give rise to specific diseases.

A great many conjectures have been hazarded as to the nature and character of the special virus of infection. For a long time the opinions of Liebig have held almost undisputed sway. According to this distinguished chemist, the morbid matter plays the rôle of a ferment exciting an action in the body, by contact, correspondent to those catalytic actions to be observed in ordinary putrefaction, and fermentation. In accordance with this view, a large number of epidemic and contagious diseases have been classed together as zymotic diseases. The investigations of Pasteur and Schröder,¹ have shown that the processes of putrefaction and fermentation are correlative of the growth and multiplication of living organisms, the germs of which are always present in the atmosphere. If the air be deprived of these germs by being filtered through cotton-wool and by passing through tubes heated to redness, no change takes place in the *fermentescible* substance.

These remarkable demonstrations throw new light upon the propagation of disease. Angus Smith assumes that both Liebig's and Pasteur's theories are true, and that "some infections may be wandering about organized, or at least as germs, and others as chemical compounds, with or without definite forms or powers of producing them."

Mr. Crookes observes on the same subject :—

"This chemical theory (Liebig's) at first sight appears very plausible; but it fails to satisfy one necessary condition in the present case. It is possible to imagine that the force set free in the declension of a complex chemical molecule to a more simple form, will be sufficient to raise a neighbouring molecule to a structure almost as complicated as the original; but according to this view the ferment would be constantly diminishing, whereas in reality it constantly increases in bulk. The hypothesis is therefore insufficient to explain the prodigious procreative power of the original particle. This power belongs only to the nature of an organized germ, capable of producing multiples of itself by a process of nutrition and subdivision."

M. Fremy (*Traité de Chimie, etc.*, tome sixième, p. 916) proposes an explanation of the facts observed by M. Pasteur, without the aid of invisible germs. He designates those substances which occupy the middle ground between immediate principles, and organs, under the terms "semi-organized substances," and "organized corpuscles." The semi-organized substances are in general, liquids, but may take form, solidify, group other bodies about them, and really organize themselves, under the influence of a force

¹ An excellent résumé of the views of these savans may be found in the elaborate *Traité de Chimie*, par J. Pelouze et E. Fremy. Tome Cinq. Art. Fermentations, pp. 203 et seq.

of organization which is a sort of vitality ; they then constitute organized corpuscles. These two forms are exemplified in the starch grain, and in the vitelline grain. M. Fremy considers yeast an organized corpuscle, which results from the association of many different organic and inorganic bodies—a solidification of the elements which compose it, under the influence of a soluble semi-organized substance, which is produced in the interior during maturation, or in the interior of the barley grain, in the form of diastase, during the germination of the barley. He sums up his views as follows :—

“1. The seed of yeast is nothing but an organized corpuscle.

“2. This corpuscle is formed as all other corpuscles in the body, by the association of many immediate principles.

“3. This organic association is determined by different influences, but especially by the action of a soluble semi-organized body, which forms itself during the maturation of fruits, or the germination of grains, and also in the interior of the yeast seeds during fermentation. * * *

“4. That which is called germination or gemmation of the yeast plant is nothing but the phenomenon of organic association—an action of an organizing body upon the soluble and organizable elements found in the fermentescible liquor.

“5. Germs of alcoholic ferments do not exist in the air.

“6. The juice of fermentescible fruits do not contain germs of alcoholic yeast : there is found in them only a sort of soluble ferment which determines the union of the organizable elements existing in the liquor which associate themselves together, producing yeast.”

These views of M. Fremy are nothing more than an elaborate statement of the doctrines of spontaneous generation. The panspermic theory of M. Pasteur seems to us to be the more reasonable of the two. Can either be applied to explain the nature and mode of action of morbid matters ? The presence in the atmosphere of so many invisible germs may serve to explain the occurrence of epidemics ; but, unfortunately, the demonstration of the existence of disease producing germs is wanting. If the views of M. Fremy be correct, we must deny the existence of the invisible germs. There are, in truth, no facts, nothing but vague analogies on which to base the zymotic theory. Beale has justly, we think (*Medical Times and Gazette*, August 18, 1866), taken exception to the doctrine. The convenience of the theory and its apparent explanation of a multitude of facts led to its almost universal adoption. But now, fortunately, we believe, for the progress of medical science, investigators have set about a study of the facts themselves, and are no longer content with a plausible explanation of phenomena.

Foremost among these is Dr. Beale. In his report to the Cattle Plague Commissioners, this able observer has, with his usual industry and with a calm and comprehensive judgment, sought to reach the bottom of the subject. He has, it seems to us, more nearly than any one, ascertained the real position, character, and mode of propagation of morbid matter. His views are embodied in the following extracts :—

“The various facts and arguments advanced in this report render it, I think, probable that the *materies morbi* or contagium of contagious diseases, like pus, is generated in the organism under certain special conditions. Like pus, I think, it has originally descended from the germinal matter of the organism. So virulent is the poison, and such is its power of living under varying conditions,

¹ He has also developed his views in the *Physiological Anatomy and Physiology of Man*, by Todd, Bowman and Beale, Part I. Also *Medical Times and Gazette*, Sept. 1865.

that having once sprung into existence, it is almost impossible to extirpate it. If, however, it were possible to destroy all the existing particles of any specific form of contagious germinal matter, it is reasonable to conclude that no new living matter with the same peculiar properties or powers, would be reproduced, unless the very same complex conditions which were present at its origin recurred."

Dr. Beale has defined in various publications what he means by germinal matter. In his edition of *The Physiological Anatomy and Physiology of Man*, p. 11, he has repeated his observations, from which we quote:—

"The simplest or most elementary organic form with which we are acquainted consists of a portion of this soft, transparent, colourless matter, surrounded by a layer of matter formed from it, which may be so thin as to be hardly visible. This latter results, in fact, from the action of external conditions upon the most external portion of the mass. Such an elementary part may be less than the $\frac{1}{1000000}$ of an inch in diameter, and may, we believe, exist so small as to be invisible. Still it is a living, and, in a certain sense, independent organism, capable of increase, and endowed with the power of giving rise to other bodies like itself. These wonderful powers, as already stated, reside not in the *formed* matter upon the surface, but in that within, which is in a *formless* but *living* state. The latter may be termed *germinal matter*."

The relation of the germinal matter to morbid matter is expressed in his report to the Cattle Plague Commissioners.

"I have shown that even with the aid of the highest powers of the microscope no differences can be discerned between germinal matter from the cell or elementary parts of the highest organism at any age or period of development, and germinal matter, of which the lowest, simplest being in existence is composed. * * * It will probably strike many as remarkable that the highest magnifying powers hitherto placed at our disposal, serve but to convince us that a minute particle of the germinal matter of the most malignant tumour, or the most rapidly growing pus-capsule, resembles in every particular that can be ascertained, a minute particle of healthy, living, germinal matter from the blood or from any tissue, and it is proved beyond a doubt by the same means of inquiry, that the living particles of germinal matter in vaccine lymph cannot be distinguished from those present in normal lymph or chyle."

The differences in properties of the germinal matter in its different situations are referred by Dr. Beale to *differences in power*—a vague term, substituting one difficulty for another. We might attempt to explain the same phenomenon by the use of Fremy's term, "the power of organic association." Whether we can explain the peculiar powers of germinal matter in an aberrant state (morbid matter, *materies morbi*) or not, the practical fact remains that such matter cannot be distinguished from purely normal germinal material, and that to accomplish its disorganization by chemical means is to destroy its life, and therefore its power of reproduction.

As we have already indicated there are no facts, nothing but analogies, to support the panspermic theory of the propagation of diseases. The researches and demonstrations of Pasteur render it *probable* that our atmosphere contains vast numbers of invisible germs floating in it. In the discussion of the action and uses of disinfectants, it will be convenient to assume the existence of these germs.

MODE OF ACTION OF DISINFECTANTS.—The term disinfection has a much wider application than its etymological signification warrants. As ordinarily employed it includes deodorization and the power to antisept. To disinfect is to destroy morbid or infectious matter; to deodorize is to

destroy offensive gases which may or may not be morbid; to antisept is to prevent or arrest the process of decay. Most of the so-called disinfectants are little more than deodorizers. The true disinfectants are comparatively few in number. Various classifications based upon these differences in properties and powers have been proposed by several of the authors now before us. Chevallier, Parkes, Angus Smith, and Crookes do not suggest specific classifications, but discuss those agents in groups according to some of their properties. Chevallier divides them according to their physical state into gases, solids or liquids, and solids. Dr. Harris proposes to classify disinfectants under four heads:—

“1. Absorbents of moisture and of noxious effluvia; 2. Oxidizers and deoxidizers; 3. Other chemical agents that break up noxious compounds; 4. Agents that form indestructible compounds with putrescent materials; or, that destroy cell-life and the cryptogamic and infusorial organisms.”

This classification has been objected to by Herbert Barker on the grounds that the first class are not disinfectants at all, and that the third and fourth classes constitute but one, “inasmuch as chemical agents that either enter into combination so as to form new compounds, or that break up compounds, act, in so far as the process is concerned, in the same way.” These criticisms are not well founded, especially as regards the 3d and 4th classes, which are chemically distinct. The 2d and 3d classes should, however, be embraced under one head. Thus Richardson includes all disinfectants under two heads: those which destroy noxious matters by oxidation, and those which arrest action of all kinds. Barker proposes to classify them under three heads; the first two of the classes being identical with those proposed by Richardson; the third being agents that physically restrain the action of the noxious compound, whereby its poisonous properties are neutralized.

The agents employed for disinfection are so numerous, and their actions so diverse, that it is extremely difficult to arrange them under any system of classification yet proposed. Some act by oxidizing, as heat, ozone, chlorine, bromine, iodine; others by deoxidizing, as sulphurous acid; some enter into combination with the noxious matter, as the metallic salts and mineral acids, and others act physically as absorbents, as fresh earth and charcoal. Many of the agents employed as disinfectants act in several modes. Thus chlorine decomposes the compounds of hydrogen with sulphur, carbon, phosphorus, etc., by entering into combination with hydrogen, forming chlorhydric acid. This chemical action is the ground of the efficiency of chlorine as a deodorant, for these hydrogen compounds are the principal offensive gases given off in the process of putrefactive decomposition. But chlorine has a disinfectant as well as deodorant power. It decomposes the vapour of water, and sets free oxygen in its allotropic state, or as ozone. Again, sulphurous acid is a powerful deoxidizer; it abstracts oxygen and passes to the state of sulphuric acid; but in addition to this property it is very destructive to the cryptogamic and infusorial organisms. Further, charcoal and fresh earth promote chemical changes, as well as physically restrain noxious gases. A consideration of these facts renders it evident that any system of classification will be defective. So much uncertainty also exists with regard to the mode of action of many disinfectants that it would be difficult to accurately assign them to classes. In order to present in an intelligible form the conclusions of the authors of the

works before us, we may adopt the classification of Herbert Barker, which is probably as little objectionable as any other :—

1. Agents that chemically destroy the noxious body.
2. Agents that hold the noxious body inactive (antiseptics) by arresting chemical change.
3. Agents that physically restrain the action of the noxious compound, whereby its poisonous properties are neutralized.

If we had any positive knowledge of the special virus of disease (morbid germinal matter, or cryptogamic or infusorial organisms), the so-called disinfectants might with great propriety be arranged in the following classes : deodorants, antiseptics or colytics,¹ and disinfectants proper.

APPLICATION OF DISINFECTANTS. I. *Agents that chemically destroy the noxious body* may be employed against gases, liquids, or solids. The leading agent of this class is heat, which acts, of course, by oxidation. Dr. Henry, F. R. S., of Manchester, proposed, in 1832, the application of heat as a disinfectant. He showed that the virus of scarlet fever and of plague contained in clothing could be thoroughly destroyed, so that they no longer possessed any infectious property, by exposure to a temperature of 212° F. Dr. Harris' very interesting monogram contains a *résumé* of Dr. Henry's experiments, and various observations made by himself, showing the great value of heat in the destruction of the special virus of disease. Barker embodies his conclusions in the following language: "When organic matters in the solid state are deposited in clothing, the exposure of the infected articles to great heat, as to steam or boiling water, is the readiest, the easiest, and the most effective method." Dr. Harris relates that Dr. Von Busch, of Berlin, eradicated the virus of puerperal fever, which obstinately adhered to the wards of the Berlin Lying-in Hospital, by elevating the temperature to 167° F. by means of common stoves. This remarkable experiment proves the utility of heat as applied through the air. Sufficient attention is not paid to the use of heat in destroying morbid matters. Hot air, steam, and boiling water may be employed whenever the circumstances admit. Hot air and steam can be used in rooms, houses, and hospital wards very readily, and boiling water is a convenient agent for destroying the virus adherent to clothing, and other fomites. The necessary temperature to accomplish these objects is not definitely ascertained. Dr. Henry concludes that as the infectious matter of cow-pox is rendered inert by a temperature not below 140° F., more active contagions are probably destructible at temperatures not exceeding 212° F. As the cryptogamic and infusorial organisms may play the rôle of infections, it is important to ascertain at what temperature they may be rendered inactive or be destroyed. Berkeley states, in his *Outlines of British Fungology* (p. 32), that the spores of certain fungi will bear a moist heat equal to that of boiling water without losing their power of germination. It may be safely asserted, as a general rule, that these organisms are not destroyed by a less temperature than that sufficient to effect their complete disorganization. Various experiments demonstrate this. Pasteur has shown, by repeated observations, that these organisms will not become developed in solutions raised to the boiling point, and then hermetically sealed. On the other hand, Prof. Jeffries

¹ The term *colytic* was introduced by Angus Smith "to express that quality, whatever it may be, by which the evident inclination to move is arrested." Derived from *καλῶν*, *I restrain*.

Wyman, of Cambridge, has recently apparently demonstrated that these organisms are developed even after all the precautions insisted upon by Pasteur have been adopted; but Prof. Wyman is, we believe, an advocate of the doctrine of spontaneous generation. It was ascertained by Dr. Henry that woollen and cotton fabrics could be exposed to a dry temperature of 220° F. without injury. There can be no doubt that this temperature would effect the chemical decomposition of most morbid matters, and even of the spores of disease-producing fungi.

Next to a high temperature, chlorine is considered by some of our authors as one of the best disinfectants. According to Herbert Barker, "for rapid deodorization and disinfection, chlorine is the most effective agent known." This conclusion was reached after numerous comparative experiments. Chevallier also places chlorine in the front rank. It is questionable whether it is deserving of the high eulogiums passed upon it. As a *deodorant* there can be no doubt of its efficacy, for it breaks up the odorous gases (hydrogen compounds) developed in putrefaction, but it does not appear to be equally effectual against the special virus of disease. Thus Dr. J. P. Loines¹ concludes, as the result of some carefully conducted experiments, that chlorine, in quantity sufficient to be irrespirable, does not destroy the infectious property of vaccine virus. Mr. Crookes has performed an experiment showing that chlorine acts first upon the gaseous products of decomposition, and that if virus or spores of fungi are to be reached, large quantities of this agent must be used. Beside the unpleasant odour of chlorine, and its irritant action upon the respiratory organs, there are other objections to its use. Thus, when liberated in rooms the walls of which are whitewashed, it enters into combination with the lime forming the deliquescent chloride of calcium. Dr. Squibb loses sight of this fact in his warm advocacy of lime-wash and chlorine fumigations.

There are various methods of generating chlorine for deodorization and disinfection. The most common is the use of chloride of lime, from which the chlorine is given off slowly, but more rapidly on the addition of an acid. As ordinarily employed it is very objectionable. It changes, as we have seen, into the deliquescent chloride of calcium, and keeps the place to which it is applied permanently damp. Chlorine can be readily obtained from chlor-hydric acid, which contains 97 per cent. of this gas, by heating it gently with peroxide of manganese; or it may be obtained by treating a mixture of peroxide of manganese and chloride of sodium with sulphuric acid. Such preparations are made on a large scale, and put up in a convenient form by manufacturers for this purpose. To regulate the supply of chlorine in the sick-chamber, Herbert Barker proposes to distribute it from half-ounce vials, at as great a distance as possible from the patient. Such a method of evolving chlorine is by no means so objectionable as sprinkling the floor of the apartment with chloride of lime, and is more efficient than suspending cloths moistened with a solution of chlorine or chloride of lime.

Ozone, as is well known, is active oxygen, and is a more powerful oxidizer than common oxygen. It attacks organic matter with great energy, but, like chlorine, its energies are expended in destroying odorous gases; the special virus or morbid matter is last of all acted upon. For disinfection of air, according to Herbert Barker, "for steady and continuous effect, ozone is the best agent known." There can be no question

¹ Medical Record, March 15, 1866.

that for the deodorization and disinfection of the sick-room or hospital ward, it is the most elegant and convenient, and also effectual agent, consistent with the comfort and safety of the patient, which can be employed for this purpose. During the last cholera epidemic we employed it with great advantage in the wards of a cholera hospital. There are certain objections to its employment in all cases. Thus, ozone has an undoubted power of inducing coryza and bronchitis, and, according to Richardson, congestion of the lungs and pneumonia may be developed in rabbits by causing them to breathe an atmosphere highly charged with it.

The method of employing ozone for the disinfection of air, is simple enough. Some sticks of freshly-scraped phosphorus may be placed in a saucer, and partly covered with distilled water. The sticks of phosphorus may be more or less covered with water, to regulate the rate of oxidation; and therefore the production of ozone. Dr. Barker has figured a convenient apparatus for regulating the supply of ozone in the sick-chamber, but the simple arrangement of which we have spoken is very convenient for the purpose, and quite as effectual as a more costly and complicated apparatus. It has been objected to this method of generating ozone that the fumes of phosphoric acid which escape are hurtful to the sick. Herbert Barker disposes of this objection by saying that "experience supplies no evidence of mischief or danger from this cause." This accords with my own observation. If, however, the small quantity of phosphoric acid may, from any cause, prove objectionable, the ozone may be obtained by another process, by moistening powdered permanganate of potassa with sulphuric acid.

Ozone may be applied to the disinfection of solids and liquids in the form of *ozonides*, of which the most important are permanganate of potassa and peroxide of hydrogen. The former has grown into important medical and surgical uses and applications; it contains oxygen as ozone, to which its extraordinary deodorant and disinfectant power is due. The peroxide of hydrogen is equally effectual and for some purposes more desirable. Thus for the destruction of organic matter in water, it is preferable to the permanganate of potassa, because it imparts neither taste nor colour to the water. The objections to its use is its cost. "Whoever cheapens it," says Angus Smith, "will do good to society."

The action of the *ozonides* does not continue long. When added to decomposing liquids and solids, they destroy odour and oxidize the organic matter very satisfactorily; but after awhile the effect ceases and the process of putrefaction is resumed. Some experiments by Barker show this conclusively. "Solution of peroxide of hydrogen was good for sixteen days, then decomposition commenced and went on with great rapidity to complete disorganization. Permanganate of potash (Condy's fluid) was bad, decomposition commencing in it on the sixth day."

Bromine and iodine act in a very similar manner to chlorine. The chemical relationship between chlorine and bromine is especially strong. Bromine decomposes the gaseous compounds of hydrogen evolved in the process of putrefactive decomposition, and also combines with the hydrogen of the vapour of water, setting free oxygen in its allotropic state. Bromine is next to chlorine in efficiency in the disinfection of air, and is superior to chlorine in the disinfection of solids and liquids. It is superior to chlorine, also, in the convenience and simplicity of its application: it is only necessary to remove the stopper from the bottle containing it when the vapour, notwithstanding its density, will rapidly combine by diffusion with the air. There

are, however, various objections to bromine; it is expensive, its vapour is irritating to the bronchial mucous membrane, and the liquid is corrosive, producing an unhealthy ulceration of those parts of the body with which it comes in contact.

Iodine possesses a power of deodorization and disinfection hardly to be anticipated from its chemical actions. Its affinity for the gaseous compounds of the putrefactive process, and for the hydrogen of the vapour of water, is much less than that of chlorine and bromine; yet, in some respects, it is preferable to either. Herbert Barker has concluded, as the result of a variety of experiments, that "in the absence of ozone, iodine, exposed in the solid form to the air, is the best;" and that "for the deodorization and disinfection of fluid and semi-fluid substances undergoing decomposition, iodine is best." In addition to its usefulness and effectiveness, iodine has the merit of being easily applied to the disinfection of both gases, and solids and liquids. There are several methods of applying it; the crystals may be simply exposed to the air in a common saucer, or the tincture may be exposed in the same way; in this case the effect is gradual and sustained. When prompter effects are desired the crystals may be vapourized by heating on a plate; the vapour is distributed through the air and the iodine is deposited in a finely-divided state on all objects in the apartment, thus keeping up the effect for a considerable period.

Theoretically nothing can be more perfect than the action of the oxidizing disinfectants which we have just considered upon noxious organic matter; but their practical utility comes far short of this. Experiments and observation show that before specific virus or septic germs are attacked, the hydrogen compounds must be destroyed; for if these products continue to be evolved the oxidizing powers of the disinfectant will be consumed before the specific virus or septic germ can be reached. All odorous substances may disappear, be broken up by oxidation, and yet the septic germs remain untouched and possessed of their morbid power. Mr. Crookes has well observed that "oxidizing disinfectants possess little, if any, continuous action. What they attack is destroyed perfectly, but what they leave has no special resistance to decomposition conferred upon it. They remove the products of decomposition, but they do not take away the power of further putrefaction.

The mineral acids and the metallic salts, employed as disinfectants, belong to the first class. Nitrous and sulphurous acids are, more properly, colytic, and will be alluded to in connection with that class. Nitric and sulphuric acid, the nitrates and sulphates, are oxidizing disinfectants; the chlorides of zinc, iron, and mercury form, with organic matter, combinations which resist change. In Chevallier's treatise (p. 132) there is a list of substances proposed as disinfectants from 1762 to 1846, amongst which we find no less than thirty acids and metallic salts; but a portion of these have stood the test of experience. We propose to examine those of most practical importance. It is obvious that disinfectants in the liquid and solid form, non-volatile, can be applied only to the disinfection of liquids and solids. We may reject, at once, the mineral acids as practically unavailable, unless employed merely to disengage gaseous disinfectants. The nitrate of lead, the sulphates of zinc, copper, and iron, and the chlorides of zinc, iron, sodium, and manganese, are the chief metallic disinfectants. These vary chiefly in price, rather than in efficiency. The nitrate of lead is the base of Ledoyen's liquid, the use of which in the Paris hospitals, according to Chevallier, was very satisfactory, but not sufficiently so to establish its

pre-eminence over the salts of iron and zinc. One of the most useful in respect to efficiency, and economical in respect to price, is the sulphate of iron, and hence it may be largely employed to disinfect sewers, privy vaults, and indeed all forms of decomposing organic matter. An objection to its use, which has prevented its employment in Paris for disinfecting the gutters, is its power of colouring black the substances upon which it acts (Chevallier), and hence the more costly, if not more efficient, sulphate of zinc is employed for disinfection of noxious matters exposed to public view. It may be useful to state that the sulphate of iron dissolves in its own weight of cold water, and that three pounds have been ascertained to be sufficient to disinfect or deodorize fifty gallons of fecal matters. Some well conducted comparative experiments are wanting to show the relative value of the sulphates of iron and zinc. It appears that the mixed sulphates, of iron and copper, and of zinc and copper, are more effectual than either acting alone. The mixed salts of zinc and copper, dissolved in water, constitute the *antimephilitic liquid* of M. Larnaudès; the proportions of the several ingredients in 1000 parts are as follows: water 975, sulphate of zinc 23, and sulphate of copper 2. This liquid was found to have an advantage over a similar solution of sulphate of iron. We find some interesting comparative experiments as to the value of the sulphate and chloride of zinc, in Herbert Barker's Hastings Prize Essay. His conclusions are stated as follows: "For the deodorization of putrescent organic matter, as well as for the preservation of fresh matter, chloride and sulphate of zinc are by far the best agents." As the result of another set of experiments he observes, "Practically there is no difference between the two salts." This is a fact of considerable importance, since the chloride of zinc is a much more expensive salt than the sulphate. The chlorides of zinc, iron, manganese, and sodium, have a comparative power of disinfection in the order in which we have just named them.

There is another agent belonging to this class whose properties have not yet been discussed—quicklime. This combined with charcoal ("calx powder") is strongly recommended by Squibb, evidently, however, on theoretical grounds. Lime is an absorbent of moisture, is destructive to organized germs, and combines with the gaseous products of putrefactive decomposition. Some experiments of Barker, which we have repeated, show that lime can hardly be considered a deodorizer at all, and that it causes a rapid evolution of ammoniacal gas, when used to disinfect putrefying organic matter. As the results of practical observation have much greater value than any theoretical view, we are compelled to assign lime to a comparatively low position in the list of disinfectants of the first class.

II. *Agents that hold the noxious body inactive by arresting chemical change.*—There are important differences between the agents of this and the preceding class. The latter attack those odorous gases developed by putrefaction, and last of all—if they possess the power—oxidize and destroy the special virus of disease. If *materies morbi* consist of dead organic matter declining in complexity of chemical constitution, then the action of oxidizing disinfectants might prove sufficient. This view of the character and actions of *materies morbi* is taught, it will be remembered, by Liebig and his school, who have given origin to the zymotic theory of disease. Angus Smith uses his term, colytic, in a sense antagonistic to catalytic; in other words, colytics, restrain or prevent that tendency to move characteristic of catalysis. Whilst some of the agents of this class may be merely

colytic, others of them manifest properties much more important than a mere power to arrest catalytic changes. There are many reasons for believing, as we have already shown, that *materies morbi* is not dead organic matter, but living matter capable of growth and multiplication, whether existing as an organism or not. Further, it appears probable that germs exist in the atmosphere, capable of growth and development when the necessary conditions are presented to them.

The agents of this class do not all act in the same manner, and hence, in their applications, they should be selected with reference to their peculiar properties. Many of the antiseptics attack with energy the *materies morbi*—the living organisms—without at all deodorizing; some act as deodorizers as well as colytics, and some appear to act chemically by abstracting oxygen and thus preventing change or decomposition.

Sulphurous acid is one of the most ancient of disinfectants. Several of the authors before us quote the lines in Homer's *Odyssey*¹ referring to the use of burning sulphur by Ulysses as a fumigating agent; and also the reference in Ovid's *Fasti* to the use of the same substance for purifying sheep. Several investigators have, within a recent period, ascribed extraordinary powers to sulphurous acid. Observing the action of this agent in arresting fermentation, Dr. Polli was led to propose the use of the sulphites in zymotic diseases, or as Dr. De Ricci prefers to style them, catalytic diseases. The extraordinary confidence at once unhesitatingly given to these statements of Dr. Polli is certainly marvellous. In the first place, it is a pure assumption that the class of diseases known as zymotic are propagated by a peculiar ferment. In the next place, admitting this assumption to be true, it is obvious that the sulphurous acid could not alter those changes induced in the solids and fluids by the ferment, and that, to be of use, it should be administered as a prophylactic, or at least before the phenomena of the disease declare themselves. Lastly, the tendency of sulphurous acid to pass to sulphuric, and the absence of any proof (except the statements of Dr. Polli) that sulphurous acid passes through the organism unchanged, renders it probable that the conversion into sulphuric really takes place. It is in the prevention of disease, then, rather than in the cure of it we may hope to use sulphurous acid with advantage. Dr. Dewar was fortunate in the application of it to arrest the spread of the cattle plague. Pleased with his success, he has sought to extend the use of his remedy to a large number of diseases to which it has no applicability; amongst others to phthisis, and in order to account for its curing his coachman of consumption he has invented a cryptogamic theory of that disease. He reasons thus: As sulphurous acid is very destructive of the cryptogams, and as it cures phthisis, *ergo*, phthisis must be caused by a cryptogamic parasite. Mr. Crookes speaks in terms of commendation of sulphurous acid as a disinfectant in cattle plague, thus confirming the statements of Dr. Dewar. Angus Smith also eulogizes its properties on chemical grounds. The sulphite of lime mixed with carbolic acid constitutes the efficient and well-known McDougall's disinfectant. The evidence now accumulated renders it certain that sulphurous acid is one of the best of all the agents proposed for disinfection. It is inexpensive, easily applied (by the combustion of sulphur), and may be inhaled in considerable

¹ Bring brimstone, the relief of evils, and fire, that I may fumigate the house.

* * * Ulysses well fumigated the house, and the court, and the hall.—*Od.* XXII. 481.

quantity without injury. There are some objections to its use. Thus, it bleaches clothing, and meeting in the interstices of the cloth the vapour of water, is converted into sulphuric acid which rots the fabric. The affinity for moisture renders the use of sulphurous acid gas, for the destruction of organic germs, more effectual than it would otherwise be, for these germs, as is well known, adhere to particles of moisture and develop most abundantly in damp situations. Mr. Crookes has published some interesting and conclusive experiments showing the power of sulphurous acid to destroy the vitality of germs. Angus Smith narrates some experiments demonstrating its extraordinary antiseptic power as shown in the preservation of fresh meat. Dr. Dewar has also experimented largely with it as an antiseptic, and has preserved meat which was afterwards eaten with great satisfaction. Indeed, there can be no question as to the colytic power of sulphurous acid, or the power to destroy germs. In addition to these important properties, it is a deodorizer of no inconsiderable value, in which respect it possesses advantages over most of the other agents of this class. In the disinfection of unoccupied rooms, hospital wards, or houses, it is preferable to chlorine; whilst the latter forms by combination with the lime of the whitewash deliquescent chloride of lime, the former unites with the lime to form the dry sulphite of lime, which continues the effect for some time after the fumigation.

It thus appears that sulphurous acid answers all the requirements of a disinfectant and deodorizer, more completely than any agent thus far considered.

The very able report of Mr. Crookes is chiefly taken up with an examination into the mode of action and uses of carbolic and cresylic acids. He presents some very striking facts. Angus Smith has also experimented largely with these agents, and has formed conclusions highly favourable to their usefulness.

Carbolic and cresylic acids (creasote) are not truly acids, and are assigned by most chemists of repute to the alcohol series. Acidity, however, is a prominent feature. Creasote prepared from coal-tar, consists of a mixture of the two acids, but according to Hlasiwetz (Crookes), creasote prepared from wood tar is a different substance.

The antiseptic power of wood tar and coal tar compounds has been known from a remote period; the latter having been the influential ingredient in the materials used in the ancient process of embalming. The power of wood smoke to preserve meat from decay is familiar to every one. Dr. Squibb proposes to utilize this practical fact; he recommends that tenement houses before being thoroughly whitewashed, be fumigated by the smoke of a wood fire burning in the cellar. This would hardly be as effectual as the application of whitewash followed by thorough fumigation with burning sulphur. A citizen of Cincinnati, without being informed as to what has been accomplished abroad, has made a compound of saw-dust, coal tar compounds, and sulphur, which he proposes to burn in a shut iron stove having a perforated cover. This is the same in principle and in respect to results as the McDougall disinfectant, which consists of carbolic acid and sulphite of lime. As carbolic acid and the coal tar compounds are not deodorant, but merely substitute one bad odour for another, it is very desirable to combine sulphurous acid with them. That carbolic acid is not deodorant is evident enough from the experiments of Angus Smith and Crookes. The latter observes, "Carbolic acid has scarcely any action on fetid gases; but it attacks the cause which produces them, and,

at the same time, puts the organic matters in such a state that it never re-acquires its tendency to putrefy."

Mr. Crookes has made a number of elaborate experiments to determine the mode of action of carbolic and cresylic acids. In the first place he demonstrates that these acids preserve meat perfectly; one per cent. of an aqueous solution of carbolic acid preserved a piece of meat for ten weeks, at the end of which time it was stewed and eaten with condiments, and could not be distinguished from fresh meat except by a faint flavour of carbolic acid. Angus Smith shows that of the two acids, the cresylic is a rather better preservative of fresh meat than carbolic. Mr. Crookes next demonstrates that these antiseptics do not owe their efficiency to their power of coagulating albumen. He ascertained that one per cent. of carbolic acid destroyed the power of yeast cells to induce fermentation, and this result was accomplished without making any alteration in these cells, which could be detected by the microscope. Carbolic acid, he next determines, does not prevent diastase converting starch into dextrine, and he therefore concludes that "it has no action on purely chemical ferments," but that "it acts by attacking vitality in some mysterious way." The last of this series of experiments determined the destructive effect of carbolic acid upon the minute organisms which accompany the process of putrefactive fermentation. He sums up the results of his very interesting and conclusive experiments and observations in the following language:—

"The powerful action which carbolic acids exert on the phenomena of life, is the most remarkable property which it possesses. It may be looked upon as the test proper for distinguishing vital from purely physical phenomena, and in most cases its action is characterized by the certainty and definiteness of a chemical re-agent. In the presence of carbolic acid the development of embryotic life is impossible, and before its powerful influence, all minute forms of animal life must inevitably perish."

For the information of those not familiar with the appearance and properties of carbolic and cresylic acids, we subjoin some remarks upon their chemical and physical characters.

Pure carbolic acid is a white crystalline solid which melts at 93° F. Cresylic acid is a liquid which boils at 400° F. Carbolic acid as obtained in the shops is usually in the liquid form, owing to the presence of water and some oily impurity. The common commercial carbolic acid contains cresylic also, to which fact the liquid state of the preparation is sometimes due, but for purposes of disinfection this could not be considered an adulteration, since cresylic acid is quite as effectual as carbolic. The preparation sold as carbolic acid would necessarily be much less valuable if its liquid state were due to the presence of water. "Commercial carbolic acid is soluble in from 20 to 70 parts of water." In actual practice a solution of carbolic acid may be applied to walls, floors, clothing, and the air saturated, as far as may be done, by suspending in it cloths moistened with the same solution. In Mr. Crookes' very striking clinical experiments upon cattle plague, fumigations of sulphurous acid were combined with the use of carbolic acid in the manner above indicated. His success during this very destructive pestilence in preventing attacks of exposed animals by destroying the septic germs, affords us great encouragement to apply the same measures for the arrest of similar human epidemics. Surely, it is much more rational to employ those agents as disinfectants which attack the living germs, the special virus, the *materies morbi*, rather than those which expend their activity upon noxious gases merely.

III. *Agents that physically restrain the action of the noxious compound, whereby its poisonous properties are neutralized.*—These are neither numerous nor important. Charcoal, wood-ashes, fresh earth-mould, lime and fine coal-dust, are the chief substances of this class. Various finely divided substances have considerable power of absorbing gases, and of promoting chemical changes, but their action is chiefly a physical one—adhesion of the gases to the solid. This power is possessed in great perfection by charcoal, which absorbs large quantities of gaseous matters. This consideration has led Dr. Squibb into rather extravagant laudation, as we believe, of his favourite compound (calx powder). We find in Herbert Barker's essay some experimental demonstrations well calculated to cool the zeal of the advocates of Squibb's compound. We are convinced of the general accuracy of Dr. Barker's statements by some observations of our own. It will suffice to state the conclusions of the author of the "Hastings Prize Essay" without wearying the reader with an account of the experiments in detail.

"With regard to the above series we learn, as the experiments in the first series have already indicated, that charcoal used quite fresh possesses a very limited deodorizing power in comparison with other substances. * * * I afterwards, on June 23d, in order to be quite satisfied, placed two pounds of intestine in roughly powdered charcoal, and another two pounds in powdered charcoal, changing it every day. The result was that decomposition proceeded without interruption, and the intestines were very offensive on the fourth day."

Dr. Barker thus states the results of another series of experiments.

"This series of experiments also shows that fresh earth mould possesses rather less power as a deodorizer than charcoal. It further indicates that wood-ashes possesses a very decided deodorizing property, being in fact but little inferior to carbolic acid. Lastly, for some days, saw-dust alone acts exceedingly well; but putrefaction when it once commences in saw-dust is developed with great rapidity."

In the absence of more effective agents it would certainly be proper to use the articles of this class; but it should be remembered that they only hold inactive and do not destroy, the noxious matters.

The report of the Metropolitan Board, which we have received since writing the above, shows how much may be accomplished by an intelligent and diligent use of disinfectants, in preventing the spread of a cholera epidemic. We are, therefore, glad to avail ourself of the important results achieved, in illustration of the principles of disinfection as set forth in the preceding pages.

The New York Board of Health have reduced the practice of disinfection to a system. They established a "Disinfectant Depot and Laboratory," where the preparation of disinfectants and experiments upon their uses were carried on under competent direction. The depot was provided with trained men and horses and wagons. Whenever a case of cholera appeared in an infected district, the disinfectants were quickly dispatched to that point, and applied in the most thorough manner.

"The process of disinfection," according to Dr. E. B. Dalton, sanitary superintendent, "consisted in putting sulphate of iron either in saturated solution, or dry if used in wet places, in privies, in all vessels containing dejections from the bowels, and in all places where such dejections had been deposited. * * * All bedding and clothing soiled or used by the patient was boiled in a solution of permanganate of potassa, of the strength of one ounce to five gallons of water for two hours, and then removed and reboiled in pure water. For purifying the

atmosphere of the room without incommoding the patient, chlorine was gradually set free by adding sulphuric acid to a mixture of binoxide of manganese and chloride of sodium."

"The plan of disinfection, already described, has given entire satisfaction, as regards the dejections, clothing, and other immediate surroundings of the patient, but frequently the recurrence of successive cases in tenement houses, showed that the power of such cases was too limited, and at an early date general fumigation of such buildings was resorted to, either with chlorine or sulphuric acid gas. The process was this: All tenants were removed from the house, being allowed to take out nothing more than the clothing then upon them. All the windows and chimneys were closed. The gas was then set free in quantity—if chlorine, by the addition of sulphuric acid to chloride of lime; if sulphurous acid, by the burning of sulphur in large open pans, supported by long iron legs. The men employed commenced the process on the upper floors, and descended, leaving the pans in operation on the different floors, and finally closed the street door—the house thus filled with gas was left undisturbed for from eight to twelve hours. It was then opened, freely aired, and the tenants allowed to re-occupy. The first house treated in this manner was an emigrant hotel, in the lower part of State Street. Three cases of cholera occurred in this house within a period of thirty-six hours, and a large number of the boarders were attacked about the same time with diarrhoea. The proprietors were notified that all guests must leave and the hotel be closed. This was promptly done. The house was then thoroughly fumigated with chlorine, and kept so for twenty-four hours, when it was opened and aired. It was then cleansed throughout and the walls fresh whitewashed. At the end of ten days the hotel was re-opened and very soon crowded with lodgers. No case of cholera or other disease of any moment has occurred there since. Subsequently to that, a large number of houses were fumigated, after cholera had occurred in them. Sometimes chlorine was the agent, and at others sulphurous acid. They have proven equally satisfactory, though in far the largest number the latter was used. In the great majority of instances, fumigation has been followed by immunity from the disease. In a few, however, cases have occurred subsequently to the process, but they have seemed the result of renewed exciting causes." (p. 22, Appendix.)

The facts which we have presented in this review, and the numerous striking instances of the power of disinfectants, contained in the works before us, but which would have occupied too much space to detail, are conclusive as to the value of these agents in the prevention of disease. Notwithstanding this, it must also be admitted, that our knowledge of the practice of disinfection is yet incomplete in many respects, but chiefly, in respect to the power of these agents to destroy septic germs. It is very desirable that this important branch of the subject be pursued by those competent to conduct such investigations. A field of research, vast in extent, is here open to those willing and able to cultivate it, and discoverers in it will be considered benefactors of their race. It is vastly more important, as we all know, to be able to prevent disease than to cure it. He who teaches us to prevent an epidemic or contagious disease by disinfectants deserves to rank with JENNER, in the estimation of mankind.

R. B.